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**TECHNICAL REPORT
NATICK/TR-99/002**

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REDUCTION OF ADDED NITRITE IN CORNED BEEF PRESERVED BY IRRADIATION

by
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TABLE OF CONTENTS

| | <u>page</u> |
|--|-------------|
| List of Tables | v |
| Preface | vii |
| Introduction | 1 |
| Materials and Methods | 1 |
| Packaging | 2 |
| Irradiation Processing | 2 |
| Evaluation | 2 |
| Data Analysis | 2 |
| Nitrosamine Determination | 2 |
| Results and Discussion | 2 |
| Nitrosamine Analysis | 7 |
| Sensory Evaluation of Samples With and Without NO ₂ and NO ₃ | 7 |
| Conclusions | 8 |
| References | 9 |

LIST OF TABLES

| Table | Page |
|---|------|
| 1. Color Evaluation of Corned Beef | 3 |
| 2. Sensory Evaluation of Corned Beef | 4 |
| 3. Color Evaluation of Corned Beef After 18-Month Storage | 5 |
| 4. Sensory Evaluation of Corned Beef After 18-Month Storage | 6 |
| 5. Consumer Ratings for Corned Beef | 6 |
| 6. Color Evaluation of Corned Beef | 7 |
| 7. Six-Month Sensory Evaluation of Corned Beef | 8 |

**REDUCTION OF ADDED NITRITE IN CORNED BEEF,
PRESERVED BY IRRADIATION**

PREFACE

The data for this report were collected by investigators from the US Army, Natick Research and Development Command during the 1970s.

It is being published now as the Army has expressed a need for irradiation sterilized meat products, Loveridge, 1994. The data is relevant.

Corned beef briskets processed with several levels of sodium nitrite (NaNO_2) (0, 25, 37.5, 50, 75, 150 ppm) and several levels of sodium nitrate (NaNO_3) (0, 25, 50, 37.5 ppm) in various combinations, were precooked, vacuum packed and irradiated with 27 kGy of gamma irradiation at -30°C (the 12-D) dose. They were evaluated for cured meat color intensities, sensory properties and nitrosamines. All the samples were found to be of acceptable quality. The color stability of the irradiated samples was best when the nitrite and nitrate were used in combination. Acceptable products can be produced without nitrate addition. Nitrosamines were not detected in any of the irradiated and nonirradiated samples.

The military requires this type of shelf-stable, whole muscle product to increase variety and quantity to the combat ration.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such item.

Introduction

Investigations on cured meat products have been directed toward reducing the amounts of sodium nitrate and sodium nitrite required for the production of cured meat products. These efforts have been motivated by the acknowledgement that nitrosamine formation in cured meats directly associated with the addition of curing salts. Research was conducted on the development of cured meats with the minimal amount of curing salts to determine which additive level produces a product with the characteristic color and microbiological safety. The US Department of Agriculture's (USDA) 1973 regulations eliminated the use of sodium nitrate (NaNO_3) as a curing ingredient in meats except for dry cured ham and fermented sausage. The approved level of sodium nitrite (NaNO_2) addition was also substantially lowered.

Wiericki and Heiligman (1973) reported extensive investigations on the reduction of NaNO_3 and NaNO_2 in irradiated ham. They reported that the additive level of NaNO_2 could be reduced to 25 ppm when used in combination with 100 ppm of NaNO_3 . Without the 100 ppm of NaNO_3 , fading of the cured meat was detected and preference scores were lowered. Wasserman (1978) reported that no nitrosamines were found in irradiated cured meats when lower levels of NaNO_2 and NaNO_3 were used. Wiericki et al. (1974) reported that the level of NaNO_2 addition could be reduced from 156 to 75 ppm in nonirradiated cured meats without affecting the quality. Wiericki et al. (1976) reported that acceptable irradiated corned beef can be produced with an addition of 156 ppm NaNO_2 without NaNO_3 . Shults et al. (1977) also showed that an addition level of 150 ppm NaNO_2 was sufficient to produce acceptable irradiated corned beef. An addition level of 25 ppm NaNO_2 also produced an acceptable product, but with decreased color intensity. Cohen et al. (1978) reported that an acceptable irradiated corned beef could be produced with the addition of 75 ppm NaNO_2 without the NaNO_3 addition.

This study was initiated to investigate the effects of low level additions of NaNO_2 and NaNO_3 on the color, acceptance and nitrosamine formation in irradiated and nonirradiated corned beef.

Materials and Methods

The raw material utilized for these studies was fresh beef brisket, pectoralis profundis muscle, excised from USDA choice grade carcasses. The briskets were trimmed of all surface fat and injecto-pumped with a Griffith #8 Big Boy™ meat pump (The Griffith Laboratories, Inc., Chicago, IL) operating at 90 Pa of pressure. The briskets were pumped to 15% added weight with the curing solutions. Each cure contained 3.0% NaCl , 275 ppm sodium ascorbate and 275 ppm sodium erythorbate. NaNO_2 levels evaluated were 150, 75, 50, 37.5, 25 and 0 ppm. NaNO_3 levels were 50, 37.5, 25 and 0 ppm. Various combinations were used. The briskets were held for 72 hours at +2 °C after pumping, prior to cooking.

The cured briskets were cooked in a water kettle at 97 ± 1 °C until an internal temperature of 80 ± 2 °C and then simmered at 75 °C for one hour. After cooking the briskets were cooled at 2 to 5 °C.

Packaging

The cooked briskets were cut into portions and packed in 404 x 202 cans, lined with an epoxy phenolic type interior enamel and closed under a pressure of $7 \pm \text{kPa}$. A mass of $330 \pm 10 \text{ g}$ was packed into each can. After closure, the cans were frozen to $-40 \pm 5^\circ\text{C}$ prior to irradiation.

Irradiation Processing

Irradiation of the corned beef was accomplished in the Cobalt 60 (Co^{60}) source at the US Army Research and Development Command, Natick, MA. The dose range was the minimum dose plus 18%; All samples received a dose of 27 to 33 kGy. The dose rate of the source was 14 kGy per kg per sec. Temperatures during irradiation were controlled at $-30 \pm 10^\circ\text{C}$ using liquid nitrogen. Samples were stored at 21 or $38 \pm 2^\circ\text{C}$ after irradiation. Non-irradiated samples were stored at $-29 \pm 2^\circ\text{C}$ after irradiation.

Evaluation

The samples were evaluated by 10 to 12 member sensory panels for the sensory characteristics: odor, flavor, color and texture in which the following hedonic scale was used: 1 - extremely poor; 2 - very poor; 3 - poor; 4 - below fair, above poor; 5 - fair; 6 - below good, above fair; 7 - good; 8 - very good; 9 - excellent.

Preference ratings were obtained by 35 member consumer panels. Evaluations for preference were made using the scale of 1 to 9, with 1 being "dislike extremely," and 9 meaning "like extremely" (Peryam and Pilgrim, 1957). A rating of 5, "neither like nor dislike", is considered the base line in determining the acceptability of the product. Samples were served cold to the panelists.

Samples were evaluated over an 18 month storage period.

Data Analysis

All of the data reported in this paper were subject to statistical data analysis using an analysis of variance and least significant differences (LSD) methods (Steel and Torrie, 1960)

Color intensities were evaluated by 15 to 20 panelists at zero time and after two hours exposure to light at $21 \pm 5^\circ\text{C}$. Samples were wrapped in clear plastic between the two evaluations to reduce the surface drying effects. All samples were compared to a color reference sample.

Nitrosamine Determination

Nitrosamine analyses were carried out using gas-liquid chromatographic techniques and mass spectrometry. The samples were shipped to the USDA Eastern Regional Center, ARS, Philadelphia, PA for the analyses.

Results and Discussion

Color intensities of irradiated cured meats have been reported to decrease upon exposure to room light (Wiericki, et al. 1973 - 1976). The addition of a small amount of NaNO_3 reduced the degree of fading in the irradiated cured meat. To further study the color changes in irradiated cured beef, samples were prepared with various levels of NaNO_2 (150, 75, 50, 37.5 and 25 ppm) and NaNO_3 (50, 37.5, 25 and 0 ppm). The samples were irradiated and evaluated over an 18 month period.

Color intensity ratings for the samples are shown in Table 1. The samples were evaluated after one week of storage. Color ratings show that the irradiated samples

without NaNO₃ added were unacceptable (5.0 or below) after two hours of exposure. In nonirradiated samples, cured with 150 ppm NaNO₂ resulted in the highest color intensity. Evaluations for color after three months of storage showed the same trends that were noted on the initial evaluation. Samples without added NaNO₃ faded significantly more after irradiation than samples with added NaNO₃.

TABLE 1 - COLOR EVALUATION OF CORNED BEEF

| Nitrite NaNO ₂ ppm | Nitrate NaNO ₃ ppm | Rating | | | | | | | |
|--|-------------------------------------|--------------------|------|----|------------------|---------------|----|--------------------|------|
| | | Irradiated | | | | Nonirradiated | | | |
| | | 0 time | mean | SD | 2 hours | mean | SD | 0 time | mean |
| A. One week storage² | | | | | | | | | |
| 150.0 | 0.0 | 4.8 ^a | 1.4 | | 4.7 | 0.9 | | 7.6 ^c | 0.9 |
| 75.0 | 0.0 | 5.5 ^{a,b} | 1.1 | | 4.7 | 1.2 | | 6.9 ^b | 1.2 |
| 25.0 | 50.0 | 5.7 ^b | 1.0 | | 5.2 | 0.8 | | 6.7 ^b | 0.9 |
| 50.0 | 25.0 | 5.6 ^b | 1.1 | | 5.2 | 1.1 | | 7.1 ^{c,b} | 0.9 |
| 37.5 | 37.5 | 6.1 ^b | 1.0 | | 5.4 | 1.1 | | 6.6 ^b | 1.2 |
| <i>F</i> | | 3.33 | | | 1.82 | | | 2.95 | 7.55 |
| significance | | 0.05 | | | NSD | | | 0.05 | 0.05 |
| B. Three months storage³ | | | | | | | | | |
| 150.0 | 0.0 | 5.3 ^a | 1.7 | | 4.7 ^b | 1.4 | | 6.0 ^d | 1.3 |
| 75.0 | 0.0 | 5.1 ^a | 1.6 | | 4.3 ^b | 1.3 | | 6.8 ^d | 1.5 |
| 25.0 | 50.0 | 6.1 ^a | 1.3 | | 5.6 ^c | 1.2 | | 6.4 ^d | 1.7 |
| 50.0 | 25.0 | 6.0 ^a | 1.5 | | 5.6 ^c | 1.4 | | 7.1 ^d | 1.7 |
| 37.5 | 37.5 | 6.4 ^a | 1.7 | | 5.8 ^c | 1.4 | | 6.4 ^d | 2.1 |
| <i>F</i> | | 2.0 | | | 3.8 | | | 1.0 | 3.2 |
| significance | | NSD | | | 0.05 | | | NSD | 0.05 |

means in a column followed by the same letter are not significant

¹ 2 hours exposure to room light, ² 19 panelists, ³ 16 panelists

Irradiation conditions - 27 kGy at -30 ± 10 °C

These samples were also evaluated by trained panelists (Table 2). When color was rated without standard reference, the ratings tended to be higher.

The panelists rated all samples highly acceptable for the sensory characteristics and no significant differences were found among the samples or among irradiated and nonirradiated samples for each of the factors tested.

TABLE 2 - SENSORY EVALUATION OF CORNED BEEF

| <u>NaNO₂</u> | <u>NaNO₃</u> | Characteristic | | | | | | | |
|---------------------------|-------------------------|----------------|-----------|-------------|-----------|---------------|-----------|----------------|-----------|
| | | <u>Color</u> | | <u>Odor</u> | | <u>Flavor</u> | | <u>Texture</u> | |
| <u>ppm</u> | <u>ppm</u> | <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> |
| <u>A. 1 week storage</u> | | | | | | | | | |
| <u>a. Nonirradiated</u> | | | | | | | | | |
| 150.0 | 0.0 | 7.1 | 0.5 | 7.2 | 0.8 | 6.4 | 1.2 | 6.5 | 1.0 |
| 75.0 | 0.0 | 7.3 | 0.8 | 7.4 | 0.7 | 6.7 | 1.3 | 7.0 | 0.9 |
| 25.0 | 50.0 | 7.5 | 0.7 | 6.9 | 1.0 | 7.1 | 1.3 | 7.2 | 0.9 |
| 50.0 | 25.0 | 7.7 | 0.8 | 7.3 | 0.8 | 7.4 | 0.8 | 7.0 | 0.6 |
| 37.5 | 37.5 | 7.4 | 0.8 | 7.2 | 0.9 | 7.4 | 0.7 | 6.6 | 1.4 |
| <u>F</u> | | 0.9 | | 0.5 | | 1.2 | | 1.1 | all NSD |
| <u>b. Irradiated</u> | | | | | | | | | |
| 150.0 | 0.0 | 7.4 | 0.9 | 7.2 | 1.1 | 6.8 | 1.4 | 6.9 | 1.3 |
| 75.0 | 0.0 | 6.8 | 1.3 | 6.8 | 1.3 | 7.1 | 1.5 | 6.7 | 1.6 |
| 25.0 | 50.0 | 7.2 | 1.0 | 6.5 | 1.4 | 6.5 | 1.3 | 7.1 | 1.0 |
| 50.0 | 25.0 | 7.5 | 0.8 | 6.8 | 1.4 | 6.7 | 1.6 | 7.5 | 1.1 |
| 37.5 | 37.5 | 7.8 | 0.8 | 6.7 | 1.7 | 6.6 | 1.4 | 6.5 | 1.2 |
| <u>F</u> | | 1.3 | | 0.3 | | 0.2 | | 0.8 | all NSD |
| <u>B. 3 month storage</u> | | | | | | | | | |
| <u>a. Nonirradiated</u> | | | | | | | | | |
| 150.0 | 0.0 | 7.0 | 0.6 | 6.5 | 0.8 | 5.8 | 1.5 | 6.7 | 0.6 |
| 75.0 | 0.0 | 6.8 | 0.9 | 6.1 | 1.3 | 5.9 | 1.3 | 6.3 | 1.1 |
| 25.0 | 50.0 | 7.0 | 0.9 | 6.7 | 0.8 | 6.2 | 1.1 | 6.6 | 0.9 |
| 50.0 | 25.0 | 6.8 | 1.4 | 5.8 | 1.4 | 6.3 | 1.4 | 7.0 | 0.6 |
| 37.5 | 37.5 | 6.9 | 0.8 | 6.1 | 0.9 | 6.2 | 1.4 | 6.7 | 0.9 |
| <u>F</u> | | 0.4 | | 0.9 | | 0.7 | | 0.7 | all NSD |
| <u>b. Irradiated</u> | | | | | | | | | |
| 150.0 | 0.0 | 6.6 | 1.6 | 6.4 | 1.4 | 5.7 | 1.8 | 6.4 | 1.2 |
| 75.0 | 0.0 | 6.5 | 1.5 | 6.1 | 1.3 | 5.9 | 1.3 | 6.3 | 1.1 |
| 25.0 | 50.0 | 6.5 | 1.1 | 6.8 | 0.9 | 6.3 | 1.2 | 7.1 | 1.1 |
| 50.0 | 25.0 | 7.0 | 1.3 | 6.7 | 1.3 | 7.2 | 1.3 | 7.4 | 1.0 |
| 37.5 | 37.5 | 6.3 | 1.4 | 6.5 | 0.9 | 6.2 | 1.4 | 7.1 | 1.0 |
| <u>F</u> | | 0.3 | | 0.6 | | 1.2 | | 1.1 | all NSD |

No significant difference between irradiated and nonirradiated sample
10 panelists per test.

Irradiation conditions - 27 kGy at -30 ± 10 °C

Also in Table 2, results of the trained panel evaluation for color, odor, flavor and texture shows that no significant effects were found among samples with various cure levels.

The samples were evaluated after 18 months of storage at 21 °C and the color intensity ratings are shown in Table 3.

TABLE 3 - COLOR EVALUATION OF CORNED BEEF AFTER 18 MONTH STORAGE

| | | Color Rating | | | | | | | |
|---------------------------------------|---------------------------------------|--------------------|-------------|-----------|--------------------|-------------|-----------|--------------------|-------------|
| <u>NaNO₂</u> <u>ppm</u> | <u>NaNO₃</u> <u>ppm</u> | Nonirradiated | | | | Irradiated | | | |
| | | <u>0 time</u> | <u>mean</u> | <u>SD</u> | <u>2 hours*</u> | <u>mean</u> | <u>SD</u> | <u>0 time</u> | <u>mean</u> |
| 150.0 | 0.0 | 7.5 ^{a,b} | 0.8 | | 6.4 ^{c,d} | 1.2 | | 7.9 ^a | 0.8 |
| 75.0 | 0.0 | 7.1 ^a | 1.0 | | 6.1 ^c | 1.1 | | 7.3 ^{a,b} | 0.6 |
| 25.0 | 50.0 | 7.8 ^b | 0.7 | | 6.9 ^{d,e} | 1.1 | | 6.9 ^{b,c} | 1.0 |
| 50.0 | 25.0 | 7.9 ^b | 0.5 | | 7.1 ^e | 1.0 | | 6.3 ^c | 1.1 |
| 37.5 | 37.5 | 7.8 ^b | 0.7 | | 7.3 ^e | 1.0 | | 6.4 ^c | 1.3 |
| <i>F</i> | | 2.46 | | 3.09 | | 6.54 | | 1.19 | |
| significance | | 0.05 | | 0.05 | | 0.01 | | NSD | |

* 2 hours exposure to room light

Means within a column followed by the same letter are not significantly different.

16 panelists Irradiation conditions - 27 kGy at -30 ± 10 °C

All the samples showed a decrease in color intensity after two hours exposure to light. Differences in the ratings for the irradiated samples after two hours of light exposure were not significant. Evaluation of the unexposed samples show that the irradiated samples without NaNO₃ were rated significantly higher in most cases than samples with NaNO₃. This did not hold true with the nonirradiated samples. Table 4 lists the sensory panel results for the irradiated and nonirradiated sample. No significant differences were found among the samples, both irradiated and nonirradiated. All the samples were rated highly acceptable for each of the characteristics.

Consumer ratings listed in Table 5 show no significant differences in the preference scores of the nonirradiated samples. In the irradiated group, the sample with 75 ppm NaNO₂ and the sample with 37.5 ppm NaNO₂ and NaNO₃ were rated significantly lower than the others. However, all samples rated within the acceptable range of 5.0 and above.

TABLE 4 - SENSORY EVALUATION OF CORNED BEEF AFTER 18 MONTH STORAGE

| <u>NaNO₂</u> <u>ppm</u> | <u>NaNO₃</u> <u>ppm</u> | Sensory Characteristics | | | | | | | |
|--|---------------------------------------|--|-----------|-------------|-----------|-------------|-----------|-------------|-----------|
| | | Color | | Odor | | Flavor | | Texture | |
| <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> |
| <u>A. Nonirradiated frozen control</u> | | | | | | | | | |
| 150.0 | 0.0 | 7.0 | 0.6 | 6.5 | 0.8 | 5.8 | 1.5 | 6.7 | 0.6 |
| 75.0 | 0.0 | 6.8 | 0.9 | 6.1 | 1.3 | 5.9 | 1.3 | 6.3 | 1.1 |
| 25.0 | 50.0 | 7.0 | 0.9 | 6.7 | 0.8 | 6.2 | 1.1 | 6.6 | 0.9 |
| 50.0 | 25.0 | 6.8 | 0.7 | 5.8 | 1.4 | 6.3 | 1.4 | 7.0 | 0.6 |
| 37.5 | 37.5 | 6.9 | 0.8 | 6.1 | 0.9 | 6.2 | 1.4 | 6.7 | 0.9 |
| <u>F</u> | | 0.4 | | 0.9 | | 0.7 | | 0.7 | |
| | | | | | | | | | all NSD |
| <u>B. Irradiated</u> | | | | | | | | | |
| 150.0 | 0.0 | 7.4 | 0.9 | 7.0 | 1.3 | 7.2 | 1.0 | 7.1 | 0.9 |
| 75.0 | 0.0 | 7.5 | 0.7 | 6.8 | 1.2 | 6.7 | 1.1 | 6.6 | 1.2 |
| 25.0 | 50.0 | 7.6 | 0.7 | 7.4 | 1.3 | 1.0 | 1.0 | 7.4 | 0.7 |
| 50.0 | 25.0 | 7.1 | 0.8 | 7.2 | 1.4 | 6.9 | 1.0 | 7.2 | 0.8 |
| 37.5 | 37.5 | 7.5 | 0.8 | 7.2 | 1.1 | 6.9 | 1.0 | 6.6 | 1.4 |
| <u>F</u> | | 0.5 | | 0.3 | | 0.3 | | 1.2 | |
| 10 panelists per test | | Irradiation conditions - 27 kGy at -30 ± 10 °C | | | | | | | |

TABLE 5 - CONSUMER RATINGS FOR CORNED BEEF

| <u>NaNO₂</u> <u>ppm</u> | <u>NaNO₃</u> <u>ppm</u> | Preference Rating | | | |
|---------------------------------------|---------------------------------------|----------------------|-----------|--------------------|-----------|
| | | <u>Nonirradiated</u> | | <u>Irradiated</u> | |
| <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> | <u>mean</u> | <u>SD</u> |
| 150.0 | 0.0 | 6.1 | 1.7 | 6.2 ^a | 1.7 |
| 75.0 | 0.0 | 6.4 | 1.6 | 5.5 ^b | 1.6 |
| 25.0 | 50.0 | 6.7 | 1.5 | 6.2 ^a | 1.6 |
| 50.0 | 25.0 | 6.5 | 1.5 | 6.1 ^{a,b} | 1.3 |
| 37.5 | 37.5 | 6.5 | 1.6 | 6.0 ^{a,b} | 1.6 |

means in a column followed by the same letter are not significantly different

35 panelists per test, 18 month storage

Irradiation conditions - 27 kGy at -30 ± 10 °C

Nitrosamine Analysis

Samples of the cured beef were subjected to nitrosamine analysis using mass spectrometry and gas-liquid chromatography (GLC). The analyses were done on samples that were both hot and served in a meal, and cold without further processing. None of the six nitrosamine compounds, DMNA, MENA, DEMA, ONMar, Onp/p and OnPyr were detected at a limit of 1 ppb in the irradiated and non irradiated cured beef samples.

Sensory evaluation of samples with and without NO₂ and NO₃

Samples of cured beef were prepared with NaNO₂ at concentrations of 0, 25, 37.5 and 75 ppm and NaNO₃ concentrations of 0, 25, 37.5 and 50 ppm in various combination. The samples were tested over a 6 month period. The results of the color analysis after 6 months of storage are shown in Table 7. The irradiated samples with 75 ppm NaNO₂ and with 25 ppm NaNO₂ - 25 ppm NaNO₃ had lower color intensity ratings at 0 and 2 hours exposure than the samples with 37.5 and 50 ppm NaNO₂. The sample without any addition did not develop the typical cured meat color and was rated unacceptable for both irradiated and nonirradiated products. No significant differences were found in the nonirradiated samples with additives.

TABLE 6 - COLOR EVALUATION OF CORNED BEEF

| | | Rating | | | | | | | |
|---------------------------------------|---------------------------------------|------------|-----|------|-----|---------------|-----|------|-----|
| <u>NaNO₂</u> <u>ppm</u> | <u>NaNO₃</u> <u>ppm</u> | Irradiated | | | | Nonirradiated | | | |
| | | 0 | | 2 | | 0 | | 2 | |
| | | mean | SD | mean | SD | mean | SD | mean | SD |
| 75.0 | 0.0 | 6.3 | 1.5 | 5.5 | 1.3 | 7.3 | 1.2 | 6.8 | 1.2 |
| 25.0 | 25.0 | 6.3 | 1.2 | 5.4 | 1.5 | 7.2 | 1.1 | 6.4 | 0.8 |
| 25.0 | 50.0 | 7.3 | 0.8 | 6.4 | 1.4 | 7.3 | 0.8 | 6.7 | 0.7 |
| 37.5 | 37.5 | 6.7 | 0.9 | 6.2 | 1.4 | 7.4 | 1.1 | 6.8 | 1.2 |
| 0.0 | 0.0 | 4.2 | 1.4 | 3.6 | 1.5 | 2.9 | 1.6 | 2.7 | 1.6 |
| <i>F</i> | | 13.2 | | 8.7 | | 32.0 | | 28.6 | |
| significance | | 0.01 | | 0.01 | | 0.01 | | 0.01 | |

13 member panel

irradiation conditions - 27 kGy at -30 ± 10 ° C

Table 8 shows the sesnsory evaluation of the samples. The samples without additive addition were rated significantly lower for color and flavor characteristics in the nonirradiated group and had significantly lower color intensity in the irradiated group. No significant differences were found between the additive samples for the other characterist

TABLE 7 - 6 MONTH SENSORY EVALUATION OF CORNED BEEF

| NaNO ₂ ppm | NaNO ₃ ppm | Characteristic | | | | | | | | | |
|--------------------------|--------------------------|------------------|-----|------|-----|------------------|-----|---------|-----|--|--|
| | | Color | | Odor | | Flavor | | Texture | | | |
| mean | SD | mean | SD | mean | SD | mean | SD | mean | SD | | |
| A. Nonirradiated | | | | | | | | | | | |
| 75.0 | 0.0 | 6.9 ^a | 1.3 | 7.3 | 1.6 | 7.2 ^b | 1.1 | 7.6 | 1.0 | | |
| 25.0 | 25.0 | 7.8 ^a | 0.8 | 8.1 | 0.5 | 8.0 ^b | 0.6 | 7.7 | 0.6 | | |
| 25.0 | 50.0 | 7.5 ^a | 0.8 | 8.1 | 0.7 | 7.6 ^b | 0.9 | 7.5 | 1.0 | | |
| 37.5 | 37.5 | 7.9 ^a | 0.8 | 7.8 | 0.6 | 7.6 ^b | 0.8 | 7.6 | 1.1 | | |
| 0.0 | 0.0 | 3.6 | 1.9 | 7.1 | 1.1 | 6.4 | 1.7 | 7.2 | 1.3 | | |
| | <i>F</i> | 20.7 | | 2.0 | | 2.9 | | 0.3 | | | |
| significance | | 0.01 | | NSD | | 0.05 | | NSD | | | |
| B. Irradiated | | | | | | | | | | | |
| 75.0 | 0.0 | 7.2 ^c | 1.5 | 7.1 | 1.1 | 6.5 | 1.4 | 7.8 | 0.8 | | |
| 25.0 | 25.0 | 7.1 ^c | 1.6 | 7.3 | 1.2 | 7.3 | 1.2 | 7.0 | 1.1 | | |
| 25.0 | 50.0 | 7.3 ^c | 1.2 | 7.2 | 1.1 | 6.9 | 1.5 | 7.3 | 1.1 | | |
| 37.5 | 37.5 | 7.5 ^c | 0.8 | 7.5 | 0.8 | 7.2 | 1.2 | 7.4 | 1.1 | | |
| 0.0 | 0.0 | 5.1 | 0.9 | 7.4 | 1.3 | 6.8 | 1.3 | 7.5 | 0.9 | | |
| | <i>F</i> | 5.1 | | 0.2 | | 0.6 | | 0.8 | | | |
| significance | | 0.01 | | NSD | | NSD | | NSD | | | |

means in a column followed by the same letter are not significantly different

10 member panel Irradiation dose - 27 kGy at -30 ± 10 °C

Conclusions

The results of these studies show that NaNO₃ addition reduces the degree of fading of the cured meat color on exposure to light. Color intensities of the unexposed samples were not increased with the addition of NaNO₃.

Acceptable irradiated cured beef products can be produced with NaNO₂ at a concentration lower than required by the USDA. Shults (1977) showed that the addition of 25 ppm NaNO₂ was sufficient to produce an acceptable irradiated product. Ionizing radiation eliminates the need for high amounts of NaNO₂ for the control of *C. boutulinum*. Therefore, it is concluded that irradiated corned beef can be safely produced with concentrations of 25 to 75 ppm NaNO₂ without any addition of NaNO₃.

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